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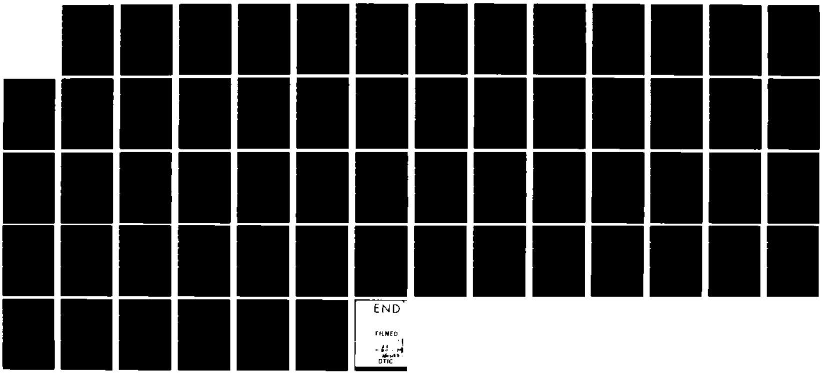

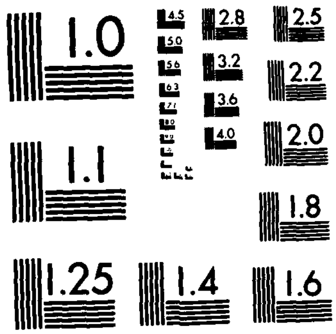

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Bolt Beranek and Newman Inc.

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Report No. 5286

Combined Quarterly Technical Report No. 28

SATNET Development and Operation
Pluribus Satellite IMP Development
Internet Operations and Maintenance
Mobile Access Terminal Network

February 1983

Prepared for:
Defense Advanced Research Projects Agency

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Quarterly Technical Report describes work on the development of and experimentation with packet broadcast by satellite; on development of Pluribus Satellite IMPs; on Internetwork monitoring; and on shipboard satellite communications.

Report No. 5286

COMBINED QUARTERLY TECHNICAL REPORT NO. 28

SATNET DEVELOPMENT AND OPERATION
PLURIBUS SATELLITE IMP DEVELOPMENT
INTERNET OPERATIONS AND MAINTENANCE
MOBILE ACCESS TERMINAL NETWORK

February 1983

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Attention: Program Management

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1 INTRODUCTION

This Quarterly Technical Report is the current edition in a series of reports which describe the work being performed at BBN in fulfillment of several ARPA work statements. This QTR covers work on several ARPA-sponsored projects including (1) development and operation of the SATNET satellite network; (2) development of the Pluribus Satellite IMP; (3) Internet Operations, Maintenance, and Development; and (4) development of the Mobile Access Terminal Network. This work is described in this single Quarterly Technical Report with the permission of the Defense Advanced Research Projects Agency. Some of this work is a continuation of efforts previously reported on under contracts DAHC15-69-C-0179, F08606-73-C-0027, F08606-75-C-0032, MDA903-76-C-0214, MDA903-76-C-0252, N00039-79-C-0386, and N00039-78-C-0405.

2 SATNET DEVELOPMENT AND OPERATION

As part of our participation in the Atlantic Packet Satellite Experiment (SATNET) during the last quarter we conducted a Supreme Headquarters Allied Powers Europe (SHAPE) Technical Centre demonstration, and performed the Satellite IMP software maintenance operations and the overall SATNET hardware maintenance operations. These tasks are described in the following sections. Some of our other activities are described below.

In this quarter, the BBN gateway between SATNET and ARPANET was decommissioned, and the associated circuit between BBN in Cambridge, Massachusetts, and the Etam Satellite IMP in West Virginia was removed from service. The VDH hardware formerly attached to the BBN gateway was subsequently shipped to the Center for Seismic Studies (CSS) in Arlington, Virginia, for installation into a newly commissioned gateway between SATNET and ARPANET. After many frustrating exchanges with the agencies involved, extending over many days, the associated circuit between the CSS gateway and the Etam Satellite IMP was made operational. The last fixes were to undo a data inversion on both lines of the circuit and to change an AT&T modem from being strapped for an internal clock to an external clock.

Having two gateways between SATNET and ARPANET, namely the CSS gateway and the DCEC gateway, improves the quality of service between those two networks and ultimately between Europe and CONUS. On those occasions when GGP packets exchanged between adjacent gateways for the determination of neighbor status are lost in SATNET, we observe one gateway declaring pathways to the European gateways down, while the other gateway is declaring them up. The existence of an alternate gateway path between two transport networks is unique in the internet system.

Because of the decommissioning of the BBN gateway, a "stub" gateway (connected to ARPANET only) was installed at the IP address 10.3.0.40 to redirect traffic being sent to the BBN Gateway. However, because the ARPANET IMP BBN40 was relocated several weeks before the circuit between the BBN gateway and the Etam Satellite IMP had been decommissioned, the stub gateway was installed earlier to permit the BBN gateway to be relocated temporarily at the IP address 10.5.0.82.

We transferred SATNET monitoring from the Information Sciences Institute (ISI) ARPANET host USC-ISID TOPS-20 computer to the BBN-NET host BBN-INOC C/70 UNIX computer. The programs RECORDER and MONITOR have subsequently been removed from among the jobs with automatic startup on USC-ISID. SATNET monitoring is now being performed by the NU monitoring system, which is also

used for monitoring the ARPANET, the WIDEBAND satellite net, gateways, and the BBN-NET, among others. Commonality of network monitoring programs facilitates software maintenance.

2.1 SHAPE Technical Centre Demonstrations

We participated in a demonstration of SATNET monitoring at a symposium held in the SHAPE Technical Centre (STC) in The Hague, Netherlands, on 9-10 November 1982. Demonstrations also included gateway monitoring, X.25 and IP network coupling, and C2 graphics, in order to provide exposure of the internetwork capabilities to a wider audience. Although the preparations were hectic, accompanied by some anxious moments in between, the demonstrations proceeded quite smoothly. Contributing to the problems seen was that long distance phone calls from the STC sometimes required half an hour to be placed; thus, we were unable to obtain assistance quickly when malfunctions developed in critical elements.

A simplified representation of the network configuration used in the demonstrations is shown below:

```
+----+           +-------+  +----+  +------+                         +----+
|    |           |       |--|BBN |--|      |                         |    |
|    |  +----+   |       |  |GWAY|  |      |   +----+   +----+       |    |
|BBN |  |BBN |   |       |  +----+  |      |   |UCL |   |RSRE|       |RSRE|
|NET |--|NET |--|ARPANET|           |SATNET|--|GWAY|--|GWAY|--|NET |
|    |  |GWAY|   |       |  +----+  |      |   |    |   |    |       |    |
|    |  +----+   |       |  |DCEC|  |      |   +----+   +----+       |    |
|    |           |       |--|GWAY|--|      |                         |    |
+----+           +-------+  +----+  +------+                         +----+
   |                 |                                                  |
   |                 |                                                  |
+----+            +----+                                             +----+
|INOC|            |ISIB|                                             |STC |
+----+            +----+                                             +----+
```

An LSI-11/23 host with a Royal Signals and Radar Establishment (RSRE) X.25 line unit interface for connection to the computer network at RSRE was established at the STC. The BBN-NET host INOC was used by BBN for gateway monitoring and SATNET monitoring, while the ARPANET host USC-ISIB was used by ISI for C2 graphics and briefing aid demonstrations. Not shown are several hosts and networks used by RSRE for demonstrating access with X.25 public data networks.

Between the Etam Satellite IMP and the STC host, the pathways used are non-redundant; a failure of any one component, whether it be a circuit, modem, processor, or satellite channel, would disrupt communications. However, the dual gateways BBN and DCEC were of considerable help in keeping the TCP links stable; namely, on those occasions when GGP packets exchanged between adjacent gateways for the determination of neighbor status are

lost in SATNET, one gateway would declare pathways to the European gateways down, while the other gateway would declare them up.

Temporarily detoured from its final destination at Patch Barracks in West Germany, the LSI-11/23 host at the STC included the following equipment:

DEC LSI-11/23 computer system
20 megabyte Winchester disk drive
8-inch double-density dual-sided floppy disk drive
4 DEC DLV-11J 4-port asynchronous interfaces
Black Box RS-422/RS-232 converters
TI Omni 800/model 840 hard-copy terminal

Terminals on the STC premises made available for the demonstrations were one each of the following:

TERMINAL	SLAVE MONITOR (TAPPED OFF THE VIDEO OUTPUT)
DEC VT100	5-foot projection color TV
DEC VT132	21-inch color TV
Newbury VDU	25-inch B&W TV
Tektronics 4014	none

Column 1 of the 5-foot projection color TV monitor was for the most part unreadable, due to a malfunction of the retrace mechanism. Because the red gun and the blue gun of this monitor were slightly out of focus, we turned these guns off to leave a green image on the screen. Similarly, we left only the yellow gun powered on the 21-inch color monitor to provide a yellow image on the screen. This monitor, which was suspended from the

wall above head level, was dedicated to running the SATNET status program LTBOX, while the other two monitors were shared. After several telephone calls to Linkabit personnel, who created the LSI-11/23 host software, the correct configuration of the host software for operation with four terminals in the STC environment was achieved.

Prior to the demonstrations, host INOC on the BBN-NET wa converted from NCP service to TCP service, concomitant with the eventual conversion of ARPANET to TCP. Because the conversio was accompanied by some difficulties, not until the day before the demonstrations had TCP access to INOC been made to work satisfactorily.

For the duration of the demonstrations, the STC host had sole use of a port on the RSRE network. When the modems on the circuit between STC and RSRE began losing carrier synchronization, RSRE personnel switched the X.25 line unit at STC to its backup modules, which seemed initially to alleviate the situation but in actuality did not effect a cure. Subsequently, following suggestions given by the British Telecom, RSRE had the modems at both ends of the circuit switched from 9600 baud to 7200 baud to effect a cure.

We observed on several occasions during the week of the demonstrations a fundamental problem in SATNET, such that user

communications between SATNET and ARPANET were blocked, while monitoring reports were being processed normally. Since monitoring reports from SATNET were continuing to be received at INOC, the Network Operations Center had no knowledge that communication through SATNET was broken. Later, the cause was traced to a bug in the SATNET Satellite IMP which consumed all the user buffers. To unblock SATNET, we had to have the Etam Satellite IMP reloaded on several occasions. Subsequently, the automatic stream facility for gateway traffic was disabled to prevent recurrence of the situation.

In the process of working with the system, we observed numerous system restarts of the STC host, presumably due to interruptions on the 220-volt primary power. Other than interrupting our TCP connections, this did not adversely affect us, because the system was set to restore the host software automatically.

We also observed that whenever a TCP connection to the EDN-UNIX was established, the RSRE gateway software would run out of buffers and cease working. This happened twice during the days of the demonstrations; thereafter, reading mail from EDN-UNIX was disallowed.

Despite all the problems mentioned above, the demonstrations went remarkably well; we were able to successfully demonstrate

reliable internetwork communications to symposium participants on four separate occasions.

2.2 Software Maintenance Operations

During this quarter, Satellite IMP versions 3.5:4 for Honeywell 316s and 4.5:4 for BBN C/30s were released. Among the changes, we added commands to cause in all sites either a synchronous restart of the Satellite IMP program or a synchronous jump to the Loader/Dumper program; we fixed a stream scheduling bug; and we incorporated patches developed since the last software release.

The major change, however, is that the source code supporting the ARPANET direct connection facility via SATNET (ARPANET line #77) was removed, and the code space was converted to buffer space, thereby increasing the buffer space by about 30%. We also implemented the averaging of the Testing and Monitoring (T&M) data generated by the second generation PSP terminal. Concurrently the NU monitoring program was changed to display the averaged T&M data.

Work on incorporating the Native Mode Firmware System (NMFS) in Satellite IMPs continued (in NMFS, the emulated machine is altered to create one more suited to communications applications,

having greater throughput capacity rd reduced latency).

2.3 Hardware Maintenance Operations

During the quarter several hardware problems appeared which we helped diagnose and, when they were related to the Satellite IMPs, fixed.

Because of a slow diminution in Goonhilly's transmit power, eventually causing serious SATNET channel degradation, COMSAT had Goonhilly site personnel insert an extra amplifier into the transmit side of the PSP terminal to bring the transmit power up to acceptable levels. (An extra amplifier was previously installed in the Tanum PSP terminal.)

When the Etam backup PSP terminal channel unit failed, satellite channel time was allocated to COMSAT for checking the unit. After it was determined that the unit could not be repaired using site personnel only, COMSAT personnel traveled to Etam with replacement parts. To restore service when on another occasion a PSP terminal unit at Etam had malfunctioned, it was necessary to reseat the Linkabit receive module many times (this module would not respond to the system reset signal or to cycling the power off and on).

Because all the PSP terminals in the field have a new CMM interface employing RS-232 protocol, the Satellite IMP cannot issue commands to any of the PSP terminals, either to reset them or to cause them to change into different states (C/30 hardware is needed). One ramification of this is that the Satellite Loader/Dumper program, which does not tolerate T&M on, no longer is able to turn T&M off. On occasions, we have had to call sites to turn T&M off manually, resulting in longer delays in the reloading of sites. We have been trying to fix the Satellite Loader/Dumper program so that T&M on is not detrimental to channel operations; however, this is currently working for C/30s but not for Honeywell 316s.

Large channel frequency drifts occurred at Goonhilly, requiring site personnel to replace the up-converter; later, the new unit showed abnormally large drifts as well. After COMSAT adjusted the uplink frequency at Raisting, we observed an 80% reduction in packet lossage on the channel. A problem in loading the Clarksburg C/30 Satellite IMP from cassette tape was traced to a malfunctioning memory chip in the microcode memory. Severe winter storms at Etam and at Tanum disrupted service.

3 PLURIBUS SATELLITE IMP DEVELOPMENT

During the quarter, activities at BBN focused on Wideband Satellite Network operations, PSAT hardware maintenance, PSAT software maintenance, and BSAT software development. The Network Operations Center at BBN assumed increased responsibility for network operations using the NU system running on BBN-INOC for network monitoring and control. With a few exceptions, the network ran fairly well during the quarter. BSAT software development during the quarter concentrated on testing and measurement of initial BSAT host processes and the Butterfly operating system's process scheduler.

3.1 Network Operations and Status

A meeting was held at Lincoln Laboratory between Western Union, Linkabit, BBN, and Lincoln on November 12, 1982 to resolve problems that had been encountered with the remote site monitoring equipment installed in the earth stations by Western Union. Western Union and Linkabit reviewed the ESI-earth station control and status interface specification. Problems at specific sites were discussed and Western Union agreed to follow up on them. The relationship between the Network Operations Center at BBN and Western Union's WESTAR Satellite Operations Center at

Glenwood, NJ was worked out. Western Union will inform the NOC of any alarm conditions in the network that are reported to them. In addition, they will get permission from the NOC before they bring any of the sites up or down.

As a follow-up on the channel performance measurements made by BBN during October, Burst Test Modem (BTM) tests conducted between Lincoln Laboratory, ISI, and SRI on December 14 indicated that there had been a severe deterioration in the quality of the satellite channel. All sites received ISI and LL with bit error rates (BER) at 3.0Mb/s of between 2*10**-2 and 9.2*10**-3. SRI was transmitting at a slightly higher level and was received better at all of the sites. Western Union determined that the other users in the Wideband Network's transponder group were transmitting at too high a level and saturating the transponders power amplifier, producing intermodulation distortion which showed up as an elevated noise floor on the Wideband Network's satellite channel. Western Union reduced the transmit power level of the other users and the BTM tests were repeated. The BERs were now less than 10**-3 except at ISI which was 1.47*10**-3. A plan is being worked out to monitor the channel performance on a regular basis.

Probe Systems made RFI (radio frequency interference) measurements at ISI during the week of January 17. Their

preliminary findings indicated that the source of the long-standing RFI problem may be signals from radar altimeters of aircraft approaching the L.A. airport. It is possible that these signals are being picked up by the antenna and aliased into the earth station receiver's frequency band by a nonlinearity in the downconverter's mixer circuits.

During the quarter, the PSAT paper tape readers at all of the sites were replaced by cassette tape readers. Cassette tapes with both a copy of the PSAT operational program and the cross-net loader program were distributed to all sites.

A PSAT was installed at RADC, Griffiss Air Force Base, Rome, NY, on December 20, 1982 and a Lincoln Laboratory Packet-to-Circuit Interface (PCI) host was installed there on January 17. On January 24, the PSAT was connected to the ARPANET as Host 1 on IMP 18. The earth station had been installed by Western Union during August 1982. At this point, however, the site is not able to operate on the channel as the Linkabit Earth Station Interface (ESI) has not yet been installed.

3.2 Network Hardware Maintenance

Due to problems in the EDN-net, the DCEC PSAT was isolated from the ARPANET and could not be reloaded during the period

November 1-15. The PSAT had been connected to an IMP on the EDN-net and lack of an IMP test program on that network hampered progress in tracking down the source of the problem. The only ARPANET IMP host port that the PSAT could be temporarily connected to was the one used by EDN-gateway, which was needed for the Internet demonstration at STC in the Netherlands during the week of November 8. Following the demonstration at STC, the PSAT was connected directly to EDN-gateway's host port on ARPANET IMP 20 and a test of the IMP's host port was successfully run by the NOC at BBN. In the shuffling of the cables, the PSAT's isolation problem on EDN-net disappeared.

On January 4, an attempt to loop DCEC off of the channel uncovered another break in the EDN-net which again isolated the PSAT from the ARPANET. It continued to be monitored and controlled via the satellite channel from other wideband sites. However, once looped off the channel, it had to be unlooped from the PSAT console. Toward the end of January, the PSAT was permanently removed from the EDN-net and connected directly to the ARPANET as Host 5 on IMP 20.

The DCEC PSAT experienced some hardware problems on January 24. BBN field service replaced a bus control unit on the lower common memory bus and a power supply on the P22 processor bus. It was finally brought up again on January 28.

The ISI PSAT experienced some intermittent hardware problems during November and December. Two of the PSAT's six processors would halt and require manual intervention to get them restarted. The source of the problem was difficult to track down due to its intermittent nature. A bus control unit and several of the bus couplers in the system were replaced. Finally on December 30, 1982 a BCP (bus coupler, processor) was replaced on the P20 processor bus and the PSAT has not had the problem since then.

Throughout the quarter, the ESI at ISI would repeatedly get itself into a "locked-up" state and not respond to PSAT RESET pulses. At times, it could be cleared from this state by power cycling the modem or the ESI control processor. On other occasions, this did not work, and the site would be left in PSAT internal loopback. Eventually, the ESI would get itself out of this "lock-up" state and begin functioning correctly. Spurious signals received from the channel or the earth station by the ESI may be the source of this "lock-up" problem. Linkabit is continuing to work on this matter.

The ESI-earth station control cable at ISI had been disconnected since August 27. At that time, it was found to be holding the earth station in RF loopback. It was reconnected on December 23 and the earth station did not automatically switch into RF loopback. However, the PSAT found the RF-loopback and

test-translator-failure status bits to be erroneously set. On December 28, an attempt was made to manually switch the earth station into RF loopback and it was found not to switch. The ESI-earth station control cable was disconnected and the earth station could then be manually switched to RF loopback. These problems have been referred to Western Union and Linkabit.

The Lincoln PSAT was isolated from the ARPANET on two occasions during January due to problems with the port expander. At the end of that month, the PSAT was temporarily left with a direct connection to IMP 10. The severe snowstorm in Boston on January 15 left quite a bit of snow in the satellite antenna. The dish has heating elements on its bottom panels, but this storm deposited snow and ice across the entire dish. A -3db attenuation in signal level on transmit and receive caused the site to repeatedly fail ranging, and it was left in loopback until January 23, when the snow had melted sufficiently for the site to hear itself again. On January 17, the PSAT was found to be running with only four processors. A bad power supply on the P20 bus was found and replaced by BBN field service on January 18.

The 125 watt high power amplifier (HPA) in the SRI earth station had burned out on January 12 and was replaced with the 75 watt spare unit on January 15. On January 17, the earth station

was found to be not transmitting. Western Union found that the spare 75 watt unit had burned out as weil. An overtemperature problem in the earth station shelter was found and corrected by Western Union. A second 75 watt HPA was then installed and the site was brought up on the satellite channel on January 20.

3.3 Network Monitoring and Control from BBN-INOC

Software was added to the Satellite NU system to allow operators to control the Wideband Network from BBN-INOC. In particular commands were added to loop, unloop, and reinitialize a PSAT. A rudimentary DDT debugger command using the EXPAK protocol was developed to aid programmers in debugging network problems from BBN-INOC. A full symbolic DDT debugger exists on BBN-TENEX. Pending the development of NU routines to handle the Internet Packet Core Protocol, PSAT cross-network loading is still done from BBN-TENEX.

An account was set up on BBN-INOC to allow Wideband Network users to get network status information and monitor their experiments.

3.4 PSAT Software Maintenance

A bug was found in the PSAT's message copying software. When messages were addressed to two different hosts on a PSAT, one of the hosts received about 20% of the packets in error. BBN is working on this problem.

When the PSAT site tables were enlarged to handle the additional six sites being added to the network, the FPODA control subframe grew to nine slots. This reduced the channel bandwidth available for datagram and stream traffic. BBN patched the software to eliminate FPODA control subframe slots for sites that were not yet on-line, thus increasing the amount of frame time available for data.

3.5 BSAT Development

BSAT development during the quarter was concentrated in two areas, the writing of new software and the measurement of Butterfly hardware and Chrysalis operating system performance.

On November 2, 1982 the BSAT system successfully sent messages from the Message Generator to the Echo Host and then to the Message Sink. All of these processes were running within one processor node without using the Chrysalis priority scheduler.

Performance severely deteriorated when these processes were run under the priority scheduler.

The BSAT development team began working with the Voice Funnel project to test the Chrysalis scheduler. As problems with the original scheduler were uncovered, a new process scheduling algorithm was devised. The new scheduler appears to work much better and was undergoing final testing at the end of the quarter, prior to being put into Butterfly microcode read only memory (ROM).

A number of sections of the Channel Protocol Module (CPM) have now been written. These include the CPM datagram aggregation and scheduling, initial acquisition, ranging, and the basic frame oriented internal sequencing of events. Code exists to make datagram reservations, send them, and time them out.

3.6 PSAT Usage of Memory Buffers

During December, BBN conducted a study of the PSAT's usage of memory buffers. This study was carried out in preparation for the design of a new PSAT buffer management system. In its current configuration the PSAT has 240 buffers, each of which is 400 bytes in length.

3.6.1 Analysis of PSAT Buffer Usage

PSAT buffer usage has been broken down into several categories. The first division is between the Host Protocol Module (HPM) and the Channel Protocol Module (CPM). Buffer usage within these two software modules is further broken down between the uplink and downlink paths.

HPM uplink:

1. 16 buffers are permanently assigned to the device input queue for each host that is up.

2. Buffers destined for the CPM or for local hosts are kept until delivered by the HPM uplink software.

3. One buffer per host that is declared up is used briefly once per second for host status messages.

CPM uplink:

1. If the PSAT is leader, it will use two buffers at all times for leader packets. Leader packets are scheduled one frame in advance.

2. Each channel stream will use two buffers at all times for stream control packets. Buffers will also be used for data packets. These buffers will be used for approximately two frames.

3. Any setup that is sent will use two buffers for two frames on the uplink. This occurrence should be relatively infrequent.

4. In addition to the data buffers, a datagram burst that is sent will use one buffer for the control packet and one buffer for the fragmentation and reassembly buffer. These buffers are held by the CPM for 19 frames (1/4 second) before being sent, unless the reservation is lost. The 19 frames include 17 frames before the reservation times out and two frames for the burst to be scheduled and sent.

5. Control packet traffic in the minimum control subframe should be fairly low (usually no more than 18 packets per minute per PSAT). Each minimum control packet will use one buffer for no more than about one frame.

CPM downlink:

1. The SATIN strip has 32 permanently assigned buffers.
2. All control packets occupy one buffer. They are held long enough to process the information, which is usually less than one frame time.
3. Data packets are held long enough to determine if they are destined for this PSAT. Data packets destined for this PSAT are immediately passed to the HPM. The number of data packets received from the channel at any time is indeterminate.

HPM downlink:

1. 16 buffers are permanently assigned to the device output queue for each host that is up.
2. All buffers containing messages destined for a local host are held long enough for the message to be delivered to the host. The amount of time this takes depends on the speed at which the host can take messages.
3. One buffer is used briefly once per minute for host status messages.

3.6.2 Model of Buffer Usage

A mathematical model was developed to describe buffer usage.

Interface buffers:

```
CPM downlink -- 32 buffers
HPM input    -- 16*NH buffers (NH = no. of hosts)
HPM output   -- 16*NH buffers (NH = no. of hosts)
```

Leader traffic:

Uplink -- 1*LDR buffers (LDR = 1 if leader, LDR = 0 if not leader)
Downlink -- 1 buffer

Stream traffic (per stream per frame, NS = no. of stream bursts transmitted per frame):

Uplink -- 2 buffers for control packets
2*NSD buffers for data packets
(NSD = no. of buffers of data in stream burst)
Downlink -- 1 buffer for control packet
NSD buffers for data packet

Datagram traffic (per datagram per frame on average, NS = no. of datagram bursts transmitted per frame):

Uplink -- 19 buffers for control packets
19 buffers for fragmentation
19*NDD buffers for data packets
(NDD = no. of buffers of data in datagram burst)
Downlink -- 1 buffer for control packet
NDD buffers for data packets

The following equation can be used to approximate steady-state buffer use:

```
BUFFERS_USED = 32 + 32*NH + 2*LDR + 1 +         /* Maintenance */
               NS [ 2(1+NSD) + (1+NSD) ] +      /* Stream traffic */
               ND [ 19(1+1+NDD) + (1+NDD) ]     /* Datagram traffic */

             = 33 + 32*NH + 2*LDR + NS[3*(1 + NSD)] + ND[39 + 20*NDD]
```

The cost of additional traffic is as follows:

1 stream burst/frame costs 3(1+NSD) buffers per frame.
1 datagram burst/frame costs (39 + 20*NDD) buffers per frame.

The following assumptions were made in deriving this model:

1. All traffic is generated by this PSAT -- no other traffic on the channel.

2. Input traffic from the hosts arrives with exactly one frame between messages and is also processed at precise intervals within the PSAT.

3. There are no setups occurring.

4. There is enough traffic being generated by this PSAT to allow ranging and reservation data to be piggybacked on data packets.

5. Buffers are assumed to be taken and freed on frame boundaries.

3.6.3 Model Testing and Results

The model was tested under several different scenarios at BBN and Lincoln Laboratory. The BBN backroom PSAT was leader (LDR=1), had a connection to the ARPANET up and no other hosts (NH=1). The Lincoln PSAT was leader (LDR=1), had a connection to the ARPANET up and two additional external local hosts active (NH=3).

1. BBN backroom PSAT, No streams or datagrams
2. LL PSAT, No streams or datagrams
3. LL PSAT, 1 stream burst/frame with 1 data buffer
4. LL PSAT, 1 stream burst/frame with 2 data buffers
5. LL PSAT, 1 datagram burst/frame with 1 data buffer
6. LL PSAT, 1 datagram burst/frame with 3 data buffers
7. LL PSAT, 1 stream burst/frame with 1 data buffers
   1 datagram burst/frame with 1 data buffer
8. LL PSAT, 1 stream burst/frame with 2 data buffers
   1 datagram burst/frame with 1 data buffer

The results are tabulated below:

Scenario	Free Buffers Predicted	Free Buffers Observed
1.	172	172-175
2.	109	110-112
3.	104	106-108
4.	100	101-104
5.	50	51-56
6.	22	30-00
7.	44	44-54
8.	41	38-49

The model seems to track the number of buffers fairly accurately, but has a tendency to slightly overestimate the number of buffers used in some of the scenarios.

3.6.4 Conclusion

It is interesting to note that in a normal running system, 99-131 buffers out of 240 are dedicated to device interfaces. This leaves 141-109 buffers left to use for traffic as it flows through the PSAT. Increasing the number of buffers in the PSAT would increase the number of buffers available to handle traffic. For example, if the PSAT had 440 buffers instead of 240, the PSAT would easily be able to transmit two datagram bursts per frame, which together contain a total of 10 buffers of data. While sustaining that level of traffic, the PSAT would still have over 30 buffers left to process traffic from other sites and absorb

any traffic fluctuations. With its current 240 buffers, the PSAT is barely able to support 1 datagram burst containing 3 buffers of data.

4 INTERNET DEVELOPMENT

4.1 Introduction

The major activity during the past quarter was the continued deployment and maintenance of the Macro-11 gateway. Other important work included enhancing NU gateway monitoring, demonstrating Gateway monitoring at the SHAPE Technical Center, and supporting the Packet Radio exercises.

4.2 Gateway Installations

New gateways were installed at several sites. The most important was at the Center for Seismic Studies (CSS), which became the second ARPANET - SATNET gateway.

A gateway was installed to support the Packet Radio exercise BRIM FROST. Other new gateways were installed at the University of Wisconsin, Purdue University, and SRI International. The current list of operational gateways is shown in the following table.

Gateway	Adjoining Networks
BBN	ARPANET - BBN-NET
BBN-PR	BBN-NET - BBN-PR
BRAGG	ARPANET - BRAGG-PR
BRIMF	ARPANET - DEMO-PR
CSS	ARPANET - SATNET
CRONUS	ARPANET - DOS-ETHERNET - FIBERNET
DCEC	ARPANET - SATNET - EDN
NTARE	SATNET - NTARE-TIU - NTARE-RING
PURDUE	ARPANET - PURDUE-NET
SRI-C3PO	ARPANET - SF-PR-2
SRI-C3PR	ARPANET - SF-PR-3
SRI-R2D2	ARPANET - SF-PR-1
UCL	SATNET - UCLNET - RSRE/NULL - UCL-TACNET
WISC	ARPANET - WISC-NET

4.3 Gateway Status Processor

We now have running in the Internet Network Operations Center (INOC) a gateway status processor, which keeps track of which gateways are up, down, or not reachable and which gateway interfaces are up or down. The display produced by the gateway status processor makes it quite easy for the operations center personnel to check gateway up-down status. An example of the display output is shown in the following figure:

Gateway Status Display

Gateway	Interface 1		Interface 2		Interface 3		Interface 4	
BBN	Arpanet	UP	BBN-net	UP				
C3PO	Arpanet	UP	SF-PR-2	DN				
C3PR	Arpanet	NR	C3-PR	DN				
CRONUS	Arpanet	UP	BBN-TC	UP	Cronus	UP		
CSS	Arpanet	UP	Satnet	UP				
DCEC	Arpanet	UP	Satnet	UP	EDN	UP		
MINET	Arpanet	UP	Minet-Tst	UP				
NTARE	Satnet	UP	Ntare-Tiu	UP	Ntarenet	UP		
PURDUE	Arpanet	UP	Purdue-CS	UP				
R2D2	Arpanet	DN	SF-PR-1	DN				
UCL	Satnet	UP	Rsre-Null	UP	Uclnet	UP	UCL-TAC	UP
WISC	Arpanet	UP	Wisconsin	UP				

Last status change: Wed Feb 23 14:22:53 1983
Time now: Wed Feb 23 15:14:58 1983

The status processor works by periodically sending out ICMP Echoes to all of the gateways. The response received from the Echo messages (Echo Reply, Destination Dead, Destination Unreachable, etc.) is used to update a status file. Changes to the status file are then output to the status display.

4.4 SHAPE Technical Center Demonstration

We gave a successful demonstration of Internet Gateway monitoring at a symposium on ADP Interoperability held at the SHAPE Technical Center (STC) in the Hague, Netherlands. The demonstration consisted of a talk describing how the DARPA Internet functioned, followed by an on-line demonstration of the

tools used to monitor and control the Internet gateways. We did this by running programs on the INOC computer, located at BBN. We were connected to INOC by running Telnet on a Fuzzball at STC, which was connected with a 7.2Kb line to the network at RSRE, in Malvern, UK. This was connected to the rest of the Internet with a line to the gateway at University College London.

4.5 Packet Radio Exercise Support

At the LOGEX Packet Radio exercise we noticed that the gateway was frequently dropping its interface to the Packet Radio network. We traced this problem to the Packet Radio network sometimes being much slower to accept packets from the gateway than the ARPANET was at sending them to the gateway. This caused the gateways' output queue to the Packet Radio network to be full for relatively long periods of time, causing the gateway to drop packets destined for the Packet Radio network. Enough of the packets dropped were GGP Interface Probes, which are sent by the gateway to determine if the network is up or down, to force the gateway to declare the network down.

This sequence of events was causing the gateway to declare the Packet Radio network down in times of congestion, further adding to the congestion. The strategy employed by the gateway to send GGP Interface probes was clearly not optimum. We changed

the gateway software to send the GGP Interface probes at higher priority. The gateway will now put one of these messages on the output queue even though it is full. This new strategy was successfully tested at the BRIM FROST Packet Radio exercise held in Alaska. The old problem did not reappear.

5 MOBILE ACCESS TERMINAL NETWORK

As part of our participation in the development of the Mobile Access Terminal (MAT) and the MAT Satellite Network (MATNET) we provided extensive support for the system integration and the ongoing large scale system testing. The system integration was divided into two major parts. First, after shipping the ruggedized Satellite IMPs #3 and #4 to E-Systems, ECI Division, in St. Petersburg, Florida, we traveled to ECI to integrate these units with the associated ruggedized Terminal Input Units (TIUs), crypto hardware, Black hardware, and radio equipment to form MATs. These MATs (one at a time) were tested at ECI on MATNET formed by MATs #1 and #2 located within the Advanced Command and Control Architectural Testbed (ACCAT) at the Naval Ocean Systems Center (NOSC) in San Diego, California. Second, we installed MAT #3 on the carrier USS Carl Vinson (CVN70) while it was docked in Portsmouth, Virginia. Meanwhile, we were involved in the system testing during and after the above installations. Because of the sparsity of available FLTSATCOM satellite time, productive use was imperative, requiring careful preparations. In order to convey the effort involved in these activities, a detailed summary of the associated events is given below, presented as a log of events for systematization of the information.

MONDAY 1 NOVEMBER - THURSDAY 4 NOVEMBER

This time was spent preparing the new ruggedized MATNET hardware at ECI for the first satellite testing session on 5 November. We installed the new equipment in laboratory racks provided specifically for the purpose of conducting tests. The rack configuration was:

```
RACK #1 -- 2 C/30 Satellite IMPs
           1 cassette tape reader
           2 cryptos
           1 ON-143

RACK #2 -- 2 LSI-11 TIUs
           2 LSI-11 Black processors
           1 cassette tape reader
           2 AN/WSC-3 radios
```

The TIUs, crypto hardware, Black hardware, and radio equipment are ECI's responsibility, while the C/30s are BBN's responsibility. Note that ECI had only enough crypto equipment on hand to support a single MATNET site; nevertheless, the sites are identified as:

```
Shore1 -- NOSC
Ship2  -- NOSC
Ship3  -- ECI
Ship4  -- ECI
```

The C/30s survived the trip to ECI with only minor mechanical damage to one of the chassis, which was later straightened out by ECI mechanical services. Diagnostics were

run successfully after the units were assembled, and subsequently the MATNET Satellite IMP code was left running for a number of overnight periods in an internally cross-patched mode. No ruggedized C/30 hardware problems were encountered at any time.

A significant amount of time was spent bringing the first ruggedized TIU on-line. Among the problems that had to be corrected were incorrect 1822 cabling, improper LSI-11 module configuration, and a malfunctioning CPU card. Since ECI had only one robustness module at this time, only one TIU could be configured for checkout of all the C/30 host interfaces. The robustness modules designated for installation in the second and third ruggedized TIUs were still located in the two Black processors at NOSC and did not arrive at ECI until after the last day of satellite tests in November. In order to release these robustness modules, ECI programmed and tested PROMs containing new Black processor code not requiring the presence of a robustness module. A Black processor with the new PROMs was used for checkout of all the C/30 Red/Black interfaces.

We brought with us cassette tapes on which were written Satellite IMP versions 6.2:1 and 6.2:2, where the former is the field release used for the shipboard demonstrations on the USS Fanning last summer, and the latter is the field release supporting a four-site network and implementing error protection

on the packet length parameter for packets sent over the satellite channel. Because the new version initially had host interfacing problems, it was used for the Red/Black interface tests, while the old version was used for the TIU checkout. Later, the host interfacing problems with version 6.2:2 were corrected.

FRIDAY 5 NOVEMBER

Due to the lack of a functional codec in the Ship2 Black processor, the first satellite test was limited to two sites. A replacement codec had been shipped quite a few days earlier but had not arrived in the proper hands at NOSC. Another codec was shipped from ECI to NOSC along with the new robustness-module independent PROMs in an effort to have an operational Ship2 site ready for Monday's tests. Consequently, only one codec was left on hand at ECI, allowing only one Black processor to be fully configured at ECI.

A two-site network was brought up running Satellite IMP version 6.2:1, but not until after sorting through a number of time-consuming problems, including malfunctions with one of the AN/WSC-3 radios at NOSC and confusion resulting from the modification of the TOPS-20 MONITOR/RECORDER/EXPAK/QUERY programs to handle a four-site network. Lack of a telephone in the ECI testing area as well as the physical separation of the various

MATNET components at NOSC made test coordination difficult (a telephone was later provided in the ECI test center). The two-site network ran without any significant problems; neither frame nor reservation synchronization was lost at the ECI site during one and one half hours of continuous operation. Telnet connections were routinely opened from the TIU at the ECI site to the ACCAT TOPS-20.

MONDAY 8 NOVEMBER

By the start of the satellite tests, the Ship2 site was still without a working codec; hence, MATNET was again restricted to two sites. In order to test a TIU-to-TIU connection (as might be used in ship-to-ship communications), the TIU connected to the non-functioning Ship2 site was temporarily moved to the Shore1 site. The two-site network was brought up, and three simultaneous Telnet connections were made: a ship-to-ship connection between the two TIUs (used for ECI/NOSC coordination) and two ship-to-shore connections from the ECI TIU to the ACCAT TOPS-20 (used for display at ECI of the MONITOR program and for general access to TOPS-20 functions).

Frame synchronization was repeatedly lost during the network operations on this date. Although unauthorized use of the satellite channel was observed with a spectrum analyzer at ECI, the channel was not being monitored closely enough to confirm any

correlation between the interference and the loss of frame synchronization. A decision was made to maintain a closer watch on the satellite channel in the upcoming tests in order to establish any such correlation.

Towards the end of the day's satellite time, the network was run using Satellite IMP version 6.2:2. Although this version could not yet run with TIU hosts, the gateway host did operate, and proper network operation over the satellite channel was confirmed.

TUESDAY 9 NOVEMBER

A working codec finally became available at NOSC for installation in the Ship2 Black processor. Time was spent debugging the Satellite IMP version 6.2:2 host interfacing problem.

WEDNESDAY 10 NOVEMBER

For the first time, all three sites were ready to participate in the network. However, at the start of the allocated satellite time, the ACCAT TOPS-20 was non-operational, and computer operators were not immediately available to restore the machine. Because the ACCAT TOPS-20 functions as the network monitoring/control host, its use is indispensible to network testing operations.

Although the new Black processor PROMs had arrived at NOSC, they could not be installed in time for the day's satellite testing. This was unfortunate, since the Shore1 Black processor halted twice during the testing session, and the PROMs contained the new version of the Black processor software with all halts removed. Because the Black processors are in a room remote from the rooms containing the Red subsystems, the cause of a system crash at NOSC is not obvious when due to a Black processor halt, and considerable time is lost with site recovery.

On this day, all three sites were brought up running Satellite IMP version 6.2:1. Numerous Telnet connections were opened from both the Ship2 site and the Ship3 site, including a Ship2-to-Ship3 link.

A close watch of the satellite channel on the spectrum analyzer at ECI revealed frequent interference from unauthorized users, often coinciding with the loss of MATNET frame and/or reservation synchronization but sometimes causing no loss of synchronization at all.

THURSDAY 11 NOVEMBER

The Satellite IMP version 6.2:2 TIU host interfacing problem was corrected, and a list of the required patches was prepared. The new PROMs were installed in the NOSC Black processors, but

one of the two sets sent did not appear to operate properly. This problem was worked on during the day, with the decision made to use the old PROMs during the next satellite tests if the problem with the new PROMs could not be resolved.

FRIDAY 12 NOVEMBER

On this day MATNET was again limited to two operational sites due to a failure of the codec-interface board in the Ship2 Black processor. Since the problem with the board could not be resolved over the telephone, a replacement board was shipped from ECI to NOSC.

Correcting a problem with the RF subsystem at ECI occupied the initial part of the day's satellite time. Satellite time was also spent isolating the source of the previously observed large global time drifts to the Ship2 C/30 hardware (this was accomplished by running the network with different combinations of site IDs and C/30 hardware). Replacement 16-MHz C/30 master crystals were then shipped from BBN to NOSC to correct the problem.

An unauthorized user was observed on the satellite channel for approximately two and one half hours. For most of that interval, the user's presence did not appear to disturb the network, although there did occur a relatively short period of

repeated synchronization loss.

Towards the end of the satellite time, the two-site network was run using Satellite IMP version 6.2:2 with the TIU host patches inserted. TOPS-20 connections were made from the ECI TIU, verifying the host interfacing problem had indeed been corrected. Thereafter, only version 6.2:2 was used.

MONDAY 15 NOVEMBER

By the start of the satellite tests, the replacement codec-interface board had been received at NOSC and installed in the Ship2 Black processor. Although all three sites ran channel tests successfully (Black subsystem only), difficulties were encountered in bringing up a three-site network due to the Ship2 Satellite IMP not being able to achieve frame synchronization. Since improper crypto keying for the Ship2 site was suspected, an authorized crypto person was called in to re-key the crypto equipment. When this failed to cure the problem, a number of cable swapping operations were made, revealing the problem to be in the Ship2 Black processor. After the problem had been isolated to this level, satellite time had expired, leaving further investigations to be done off-line.

The problem was traced to the new codec-interface board, which had just been installed. The new board is not identical to

the old board, since the new board has the quality monitoring circuitry integrated onto the board, requiring some Black processor backplane rewiring. Because the Black processors at the NOSC sites did not have the wiring modifications, every received packet had been flagged as a contention packet by the quality monitoring circuitry and was deliberately corrupted so as to be received in error on the Red side. Hence, the Satellite IMP could not receive its round-trip timing packets and thus could not achieve frame synchronization. In order to have the Ship2 site operational during the next testing session, a temporary wiring change was made on the new board, which was successfully tested by looping the Satellite IMP through the Black processor.

For a brief time during the day's satellite tests, ECI was reconfigured as the Ship4 site, and the four-site network monitoring software was run on the TOPS-20 with no problems encountered.

TUESDAY 16 NOVEMBER

On this day there were failures in four distinct parts of the system.

First, a problem in the operation of the PLI at NOSC, indicated by a failure of the PLI to assert its IMP-READY line,

did not allow MATNET monitoring reports to reach the TOPS-20; hence, we were without network monitoring. After several hours, the problem was corrected by reloading the PLI.

Second, the Ship2 Black processor would not run properly, which was eventually traced to a malfunction in the MXV11 multifunction card. Fortunately, another such card was available at NOSC. After many strapping changes to convert to MATNET operation, the new card was installed, and the site became operational.

Third, before the Ship3 site came on the air, a routine Red/Black interfacing check revealed an intermittent problem in the crypto equipment. The problem at times would disappear, although never for long enough to bring the site onto the network. Since the NOSC Satellite IMPS could hear round-trip timing packets from the ECI site, the problem was believed to be in the ECI crypto receive side. After various crypto machinations, the crypto at ECI began to operate properly, but this was after the allocated satellite time had expired.

Fourth, the second and third TIUs, when checked out at ECI using the single available robustness module, would not work. Eventually we determined that new metallic labels that had recently been affixed to the PROMs on the robustness module created electrical short circuits between pins on adjacent

boards. When the labels were replaced, proper operation of all TIUs was achieved. Yet another malfunctioning LSI-11 CPU card was found in this process.

WEDNESDAY 17 NOVEMBER - THURSDAY 18 NOVEMBER

This time was spent with the installation and checkout of the Ship3 MAT hardware in the new shipboard racks to be installed on the USS Carl Vinson. First, wiring errors had to be corrected on the tape cassette device selector switch for determining whether the TIU or the C/30 is to be loaded. Once configured, the equipment was tested in the racks by looping the Satellite IMP through the Black processor and by separately checking all C/30 host and Black subsystem interfaces. A special 150 foot cable was used between the crypto equipment and the Black processor for these tests in order to reveal any signal degradation on long lines. With the arrival of a robustness module, a second TIU was configured.

Out of a total of 38 hours of satellite time available in November, we were able to run three sites simultaneously for no more than three hours due to the difficulties encountered. Despite the rather disappointing performance from an operational point of view, we were able to shake down much of the system. In addition, from these tests we can draw the following conclusions.

1. At NOSC, where the equipment is distributed in four widely separated rooms, monitoring the satellite channel while participating in network operations was difficult. In contrast, at ECI, where the equipment setup is all in one room only, we were routinely monitoring the channel with a spectrum analyzer.

2. Lack of spares at the sites required multiple cross-country transits of equipment. Despite overnight deliveries by Federal Express, equipment normally would not be available for use during the satellite tests the following day.

3. Non-standardization of hardware hurt us on several occasions.

4. Unauthorized use of the channel was seen repeatedly, although sometimes it did not adversely affect MATNET communications.

5. Shared assets at NOSC means the equipment must be reconfigured before each test, increasing the risk that the site is unprepared.

6. Without a definite commitment to keep all MATNET related tools operational on a 24-hour basis, there were functional outages when the ACCAT TOPS-20 crashed one night and when the ACCAT PLI crashed another night.

7. During those times when simulation programs were running on the ACCAT TOPS-20, system response was noticeably poor.

8. Lack of terminals proved an annoyance.

THURSDAY 2 DECEMBER - WEDNESDAY 8 DECEMBER

By the beginning of December, after the Ship3 MAT was moved from ECI to the USS Carl Vinson, we traveled to the ship to integrate and test this unit on MATNET. Although only a small amount of FLTSATCOM satellite time was available for these purposes, we reached a milestone when four sites were successfully able to communicate with each other; these sites

were:

Shore1 -- NOSC
Ship2 -- NOSC
Ship3 -- USS Carl Vinson
Ship4 -- ECI

However, the shipboard installation did have its share of problems. A crypto malfunction kept the site off the net for several days; the crypto was eventually replaced. Due to a long delay inserted into the shipboard transmissions, the beginning of packet, where the Unique Word is inserted, was corrupted. Because of a problem with the ship's cabling, the pulse blanker signal appeared to always be asserted (the entire packet blanked). When the robustness card in the NOSC TIU was removed, the address stored in DIP switches on the card was destroyed. On the ship, telephones and a spectrum analyzer were inconvenient to operations.

For these tests, ship's personnel were able to free up for the TIU only one terminal, an HDS Concept 100 CRT terminal, which has the peculiar characteristic of generating a BREAK signal whenever a user types too fast. The TIU, upon receiving a BREAK signal, would infer a framing error and would immediately jump into ODT (the LSI-11 debugger program), thereby halting all operations. Adding to the difficulties, the cable from the CRT terminal was too short and was prone to pulling off the TIU

connector. To compound this problem, cramped quarters made inspecting cables difficult.

FRIDAY 17 DECEMBER - WEDNESDAY 22 DECEMBER

In the second half of December, the FLTSATCOM satellite time allocated for MATNET testing was a total of six consecutive days. In contrast with November's satellite tests, these satellite tests were quite successful; below is a summary.

In preparation, Satellite IMP version 6.2:3 software was assembled and written on tape cassettes for checkout. The major change in this version is that each site receives a specific cassette tape requiring no patches whatsoever; in site preparation, the tape is loaded, after which the site immediately accesses the satellite channel with the correct addresses and host configuration. In these tests, the Satellite IMPs were modified to perform channel scheduling factoring in priority only. Previously, channel scheduling was based on priority combined with delay class.

There was hope that Ship3 would participate, but that never happened; participation would have required the USS Carl Vinson to give up its secure voice capability during the brief interval of its test, a sacrifice which the ship was unwilling to do. To participate, the ship requires crypto equipment designated for

MATNET.

Except for the last day, the three land-based sites were on the air virtually problem free the entire time. None of the numerous hardware problems plaguing the November tests occurred; consequently, the seemingly endless shipping of hardware between ECI and NOSC was avoided. The only problem encountered was that severe storms in California on 22 December caused a primary power outage at NOSC, thereby completely eliminating both the capability of running MATNET monitoring programs and the participation by the Shore1 and Ship2 sites.

The December tests were run primarily by NOSC personnel with large amounts of our time writing detailed instructions and talking on the telephone to assist them. One satisfying conclusion of these tests is that on-site personnel have developed the capability to conduct tests without our presence.

These tests were designed to obtain some preliminary delay/throughput information; message generators were enabled in all sites, while statistics were being collected in the ACCAT TOPS-20. The message traffic for these tests was generated with constant interarrival time and with constant length -- short (3 interleaver blocks), long (9 interleaver blocks), and mixed short-long. Afterwards, test data were mailed to BBN for analysis (unfortunately we cannot view the monitoring information

directly, because it is collected in a Red area).

Early reports indicate the results are good. Some unauthorized channel interference has been seen on a spectrum analyzer, but the effect appears to be minimal. Synchronization of the different sites appears not to have been a problem.

WEDNESDAY 5 JANUARY - FRIDAY 14 JANUARY

In these tests, more delay/throughput information was collected for message traffic generated with geometric distributions of interarrival time. Only the Shore1 and Ship2 sites participated on the net, because ECI did not receive the right crypto key to allow access by the Ship4 site.

MONDAY 17 JANUARY - FRIDAY 21 JANUARY

We traveled to NOSC specifically to peform contention tests on the network during this time. In preparation, Satellite IMP version 6.2:4 software was assembled and written on tape cassettes for checkout. The major change in this version is that channel scheduling is done by factoring in priority only; tests in December demonstrated the feasibility of this change. In the following tests only version 6.2:4 was used.

In order to verify that the test procedure was correct, the contention tests were divided into three separate experiments,

two of which were designed as experimental control.

In Experiment #1 (non-contention, experimental control), the AN/WSC-3 transmitter for each site was checked for nominal power and frequency settings, and each Black processor's quality monitoring threshold was set to its maximum value, effectively disabling the quality monitoring circuitry. After the usual Black-subsystem-only satellite channel tests were performed at each site, MATNET was brought up running the FPODA satellite channel scheduling protocol. In order to generate regular, recurring traffic, each Satellite IMP's channel protocol module was patched to transmit a control packet in every PODA frame, whether or not there were any reservations or acknowledgments to be sent. Since each site transmitted its control packets in its designated slot in the control subframe, no packet contentions were being forced.

When MATNET was operated in the above mode for a period of one hour, there was no loss of synchronization by either site other than during a two minute interval when unauthorized use of the satellite channel was confirmed via a spectrum analyzer. TOPS-20 MONITOR reports, Satellite IMP statistics, and Black processor statistics all verified the correctness of the channel protocol module patches; i.e., each site was indeed transmitting a control packet in every PODA frame.

Surprisingly, the Black processor data for Experiment #1 show that 7% more unique words were detected by the Ship2 site than were transmitted; 14,011 non-contention packets were transmitted by the two sites combined, compared with 15,017 unique words detected by Ship2. However, 1,215 packets of undecodable size were recorded by the Ship2 site, which is consistent with the number of false unique words detected. The detection of unique words that do not correspond to transmitted packets is undesirable since it causes the Black processor to block the satellite channel for an interval corresponding to the size of at least a single-block packet, during which time real packets are lost. Sometimes a packet length value larger than a single block passes the validity test, and the channel is blocked for longer intervals. Note, the error detecting code that is used for the packet length field will detect all 1-bit and 2-bit errors. However, in the case of random data being received in the Black processor, the probability that a packet length value passes the validity test is 10/256.

In Experiment #2 (contention), the experimental configuration was identical to Experiment #1 with the exception that both Satellite IMPs were patched to transmit their control packets in the same control subframe slot. This was done to force constantly recurring collisions of control packets on the satellite channel. In order to remove all normal traffic from

the channel, the generation of MONITOR reports was disabled in both sites and the MATNET gateway was halted.

When MATNET was operated in the above mode for a period of one hour, frame synchronization was repeatedly lost by both sites, even though no outside interference was ever observed on the satellite channel. The Shore1 site lost frame synchronization more frequently, at intervals varying from about 30 seconds to about 4 minutes. With such frequent loss of frame synchronization, the network is totally unusable.

We hypothesize that the following specific sequence of events could be occurring, causing the loss of frame synchronization:

1. Despite contention on the satellite channel, the Black processor acquires the unique word of one of the contention packets. The packet-length value, sometimes incorrectly large, passes the Black processor validity test, and the packet is clocked through the crypto to the Satellite IMP.

2. The Satellite IMP microcode in examining the stream of data from the crypto finds a SYN character followed by a legitimate packet length parameter and 4-bit parity combination. Occasionally packet length values very much larger than the actual packet length pass the parity check and are accepted as valid by the microcode. In such cases, the microcode will not generate a satellite input complete interrupt until the number of bits corresponding to the corrupted packet length has been received.

3. With a lightly loaded channel, a period of 10 seconds is insufficient for the Black processor to clock enough bits through the crypto corresponding to the corrupted packet length.

4. When no satellite input complete interrupt occurs during a 10-second interval, the Satellite IMP macrocode resets the satellite channel interface and declares a loss of frame synchronization (the inability of a Satellite IMP to hear even a single one of its own hello packets during this length of time indicates a severe problem somewhere in the channel).

The plausibility of this sequence of events is experimentally confirmed by several pieces of evidence. First, in Experiment #2, multi-block packets were accepted as valid by the Black processor even though only single-block packets were transmitted; in Experiment #1, this discrepancy never occurred. The improper decoding of the number of blocks in a packet is undesirable, since the satellite channel will be blocked by the Black processor for an interval corresponding to the size of the improperly decoded packet-length value, during which time packets are lost. Second, the value in the FALSE-SYN counter that is kept by the Satellite IMP was 46 times higher in Experiment #2 than in Experiment #1. (Whenever the microcode finds a SYN character in the satellite input bit stream, while the subsequent packet length value is rejected due to a parity check error, the FALSE-SYN counter is incremented, and the microcode begins hunting for another SYN character.) Although FALSE-SYNs represent packet lengths that were rejected and therefore do not block the satellite input, the large increase in the FALSE-SYN count indicates a greater likelihood of a corrupted packet length being accepted. Note, the error detecting code that is used for the

packet length field will detect all 1-bit and 2-bit errors. However, in the case of random data being sent to the Satellite IMP, the probability that a packet length value passes the validity test is 1/16.

In Experiment #3 (contention, experimental control), the experimental configuration was identical to Experiment #2 with the exception that the Satellite IMPs were connected through the digital satellite channel simulator instead of over the FLTSATCOM satellite channel. Stable network operation was verified for a period of one hour, confirming the ability of the Satellite IMPs to maintain synchronization while contention packets are discarded.

The results from these experiments unambiguously indicate that the current implementations of the MATNET Red and Black subsystems cannot provide reasonable system performance when contention packets occur on the satellite channel. Network performance is so severely degraded, apparently due to the inability of the system to correctly determine packet boundaries of contention packets, that synchronization of all sites cannot be maintained. Because of the frequent loss of frame synchronization in these experiments, no assessment of the usefulness of the Black processor quality monitoring circuitry was obtained.

Note that outside interference has been observed many times during the January MATNET tests (because the interference repeatedly occurred on the hour, we can conclude that its cause is external to our system). Such interference often affects experiments that are in progress.

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